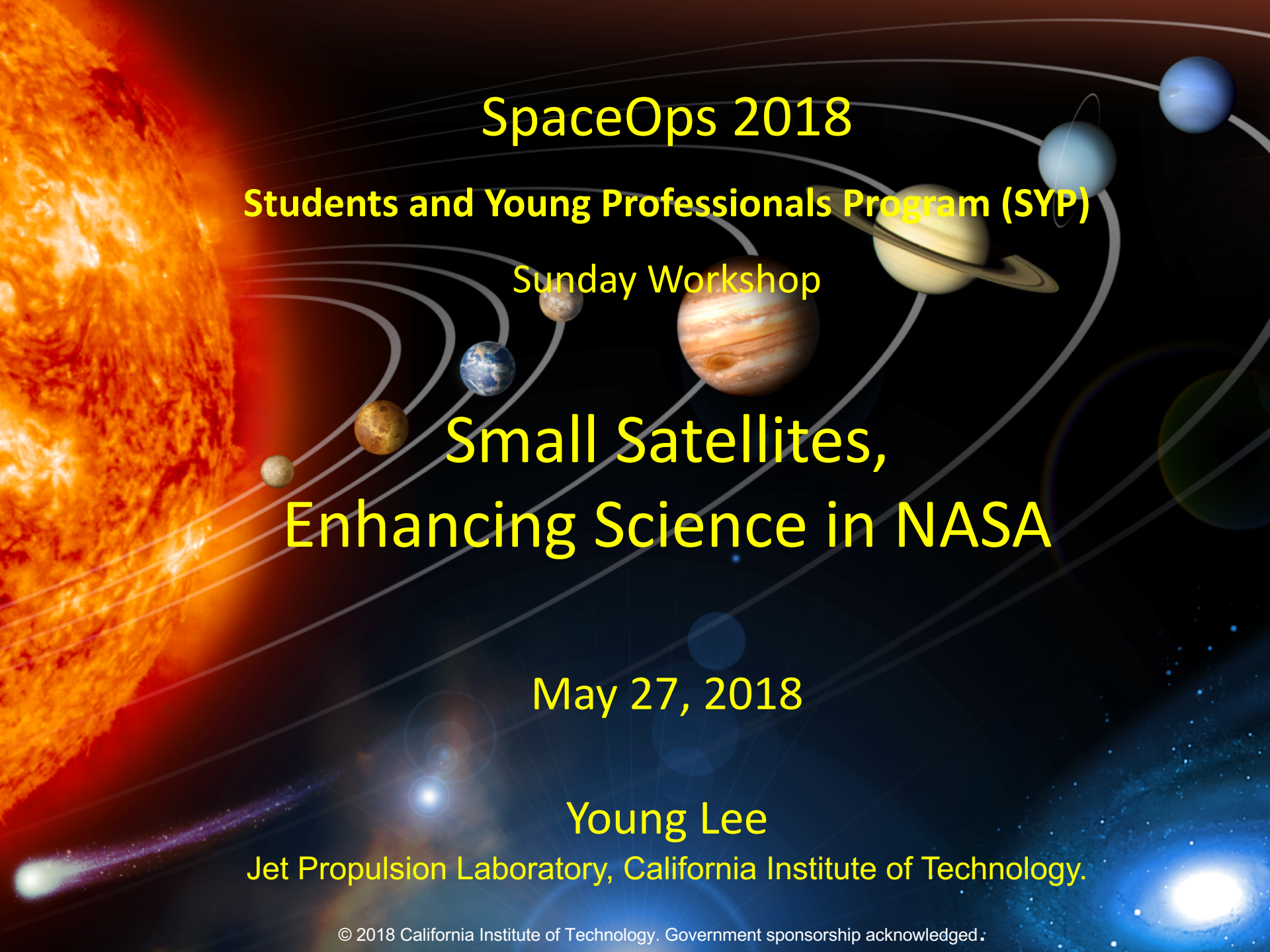


SpaceOps 2018

Students and Young Professionals Program (SYP)

Sunday Workshop

Small Satellites, Enhancing Science in NASA

May 27, 2018

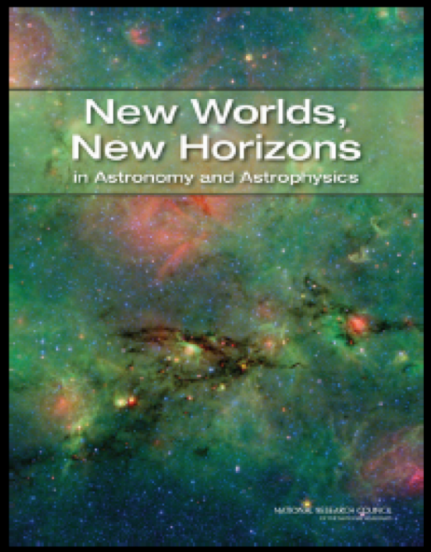
Young Lee

Jet Propulsion Laboratory, California Institute of Technology.

Note: Excerpt from the "Science Mission Directorate Class D Town Hall" presented by Thomas Zurbuchen in January 2018

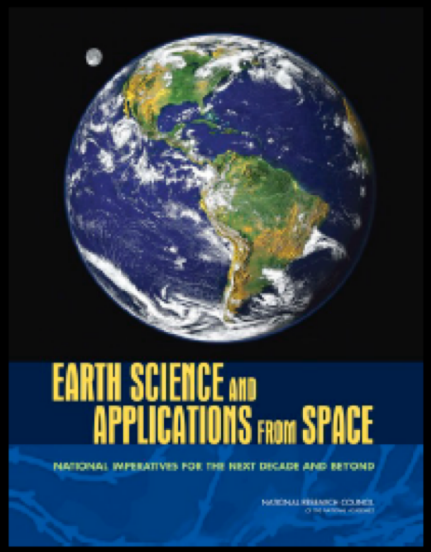
The Decadal Surveys

Astrophysics



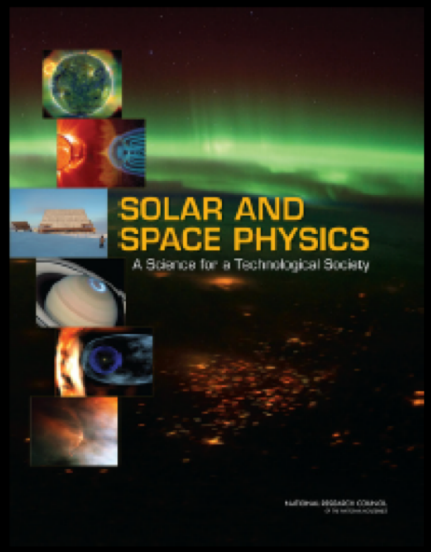
2012 – 2021

Earth Science



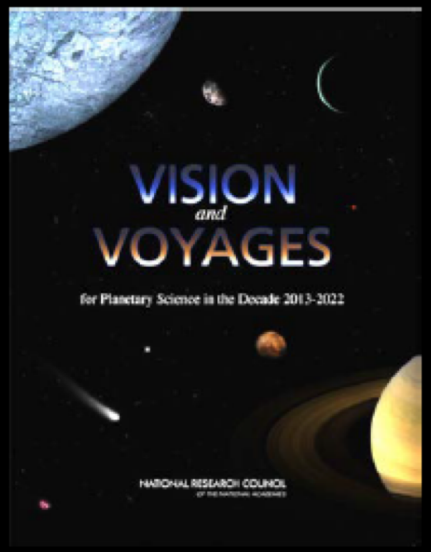
2007 – 2016

Heliophysics



2012 – 2021

Planetary

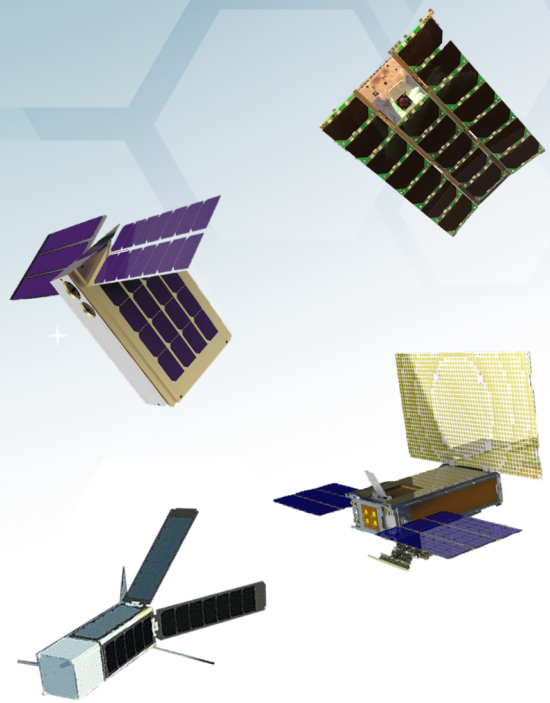


2013 – 2022

Organized by the National Academies on behalf of NASA establishing USA national priorities for scientific observations, as identified by the community, within a 10-year time frame

Note: Excerpt from the "Science Mission Directorate Class D Town Hall" presented by Thomas Zurbuchen in January 2018

Importance of Small, Innovative Missions



- **Expand** science programs to take advantage of small satellite rapid innovation to achieve breakthrough science
- **Enable** fast access to space with focused science measurements to fill a critical gap between large flight projects
- **Leverage** technology investments to further improve potential of science instruments
- **Partner** with commercial entities to acquire new capabilities of small satellite platforms

Note: Excerpt from the "Science Mission Directorate Class D Town Hall" presented by Thomas Zurbuchen in January 2018

CubeSat Symposium

- Achieving Science Goals with CubeSats Symposium held in Irvine Sept 2015 by Space Studies Board under the auspices of the National Research Council
  - Held to gather information from the CubeSat community to develop a set of recommendations for NASA and others
- Discussed CubeSats technology, and use of CubeSats for heliophysics, planetary science, astronomy and astrophysics, earth science, and technology development
  - Agenda can be found at *http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_160539*
- Resulted in wide participation, including:
  - Ames, Marshall, Goddard, JPL, APL, NASA HQ
  - SWRI, Aerospace Corporation, Lockheed Martin, Ball Aerospace, other industry
  - Many universities
- Discussed CubeSat paradigm:
  - Short development cycle
  - Frequent flights
  - High risk tolerances
  - Learn lessons from successes and fly again

Two NASA CubeSat Studies

STUDY #1: Internal NASA Study of New Opportunities for Low-Cost Science Instruments, Platforms, and Mission Architectures
Chairs: Michael Seablom/SMD and Andy Petro/STMD

(a) Investigate current paradigm shifts in the miniaturization of science instruments and disruptive small satellite platform technologies;

(b) Determine the potential for novel approaches that could break the cycle of "larger but fewer" expensive missions;

(c) Identify key SMD science measurement requirements that could be satisfied through such paradigms;

(d) Identify technology gaps to address through solicitations to remove barriers to alternative paths.

STUDY # 2: SMD sponsored NAS Study Achieving Science Goals with CubeSats
SSB Ad Hoc Committee
Chair: Thomas H Zurbuchen, University of Michigan

(a) Review the current state of scientific potential and technological promise of CubeSats;

(b) Review the potential of CubeSats as platforms for obtaining high-priority science data;

- From recent decadal reviews, Science priorities in 2014 NASA Science plan

(c) Provide a set of recommendations on how to assure scientific return on future federal agency support of CubeSat programs;

Note: Excerpt from the "CubeSats and Small Bodies Missions" presented by STMD and SMD Reps at the 14th Meeting of the NASA Small Bodies Assessment Group at Monrovia, CA on January 27-29, 2016

Improving Mission Success of CubeSats

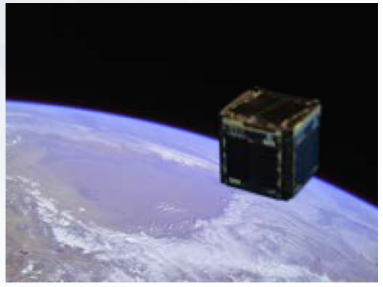
Motivation of the Workshop

- There has been a substantial increase in CubeSats launched since 2013
- University-led CubeSat projects lack the repeatable process rigor routinely found in industry
- Commercial off-the-shelf (COTS) solutions fall short of a space-qualified pedigree
- A recent National Academies report recommends that NASA and the National Science Foundation (NSF) make greater use of CubeSats for science missions
- As the importance of CubeSat payloads and missions increases, what aspects of mission assurance can significantly improve mission success rates?

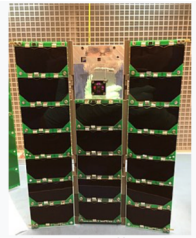
Note: Excerpt from the "Improving Mission Success of CubeSats" presented by SSL, Boeing and Aerospace Corp at U.S. Space Program Mission Assurance Improvement Workshop at El Segundo on May 2-4, 2017

NASA Sponsored Small Missions Completed

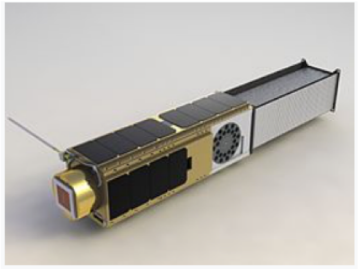
- Earth
  - IPEX



- Heliophysics
  - MinXSS



- Planetary
  - O/OREOS

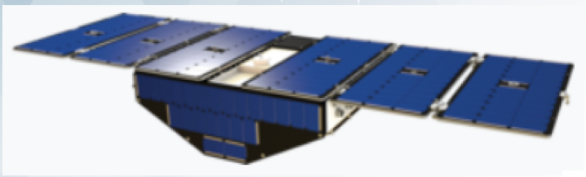


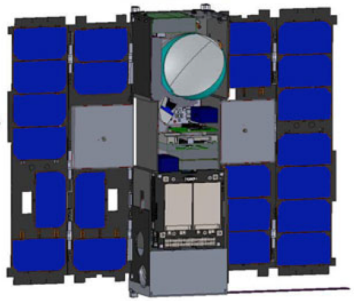
JPL-led or JPL participation

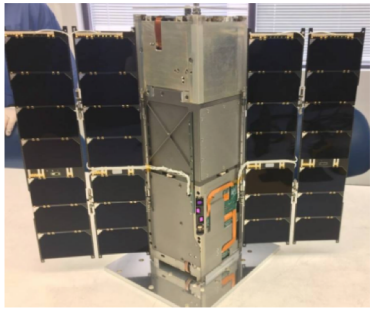
Note: Small Spacecraft Systems Virtual Institute Maintains Mission Inventory https://www.nasa.gov/smallsat-institute

NASA Sponsored Small Missions Operations Phase

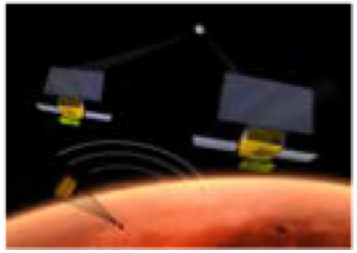
- Earth
  - CYGNSS,
  - GRIFEX,
  - IceCube,
  - MC/COVE-2,
  - MiRaTA,
  - RAVAN







- Planetary
  - MarCO (A/B)



JPL-led or JPL participation

Note: Small Spacecraft Systems Virtual Institute Maintains Mission Inventory https://www.nasa.gov/smallsat-institute

NASA Sponsored Small Missions Implementation Phase

- Earth
  - CIRAS, CIRiS-BATC, CSIM-FD, CubeRRT, HARP, LMPC (AC9), PREFIRE, RainCube, TEMPEST-D, TROPICS
- Planetary
  - ArgoMoon, BioSentinel, LunIR, LunaH-Map, Lunar Flashlight, Lunar IceCube, NEAScout, Q-PACE
- Heliophysics
  - AERO, CeREs, CIRBE, CuPID, CURIE, CuSP, DALI, ELFIN, GTOSat, LAICE, LLITED, PetiSat, REAL, SORTIE, SPORT, TBEx
- Astrophysics
  - BurstCube, CUTE, HaloSat, SPARCS

JPL-led or JPL participation

Note: Small Spacecraft Systems Virtual Institute Maintains Mission Inventory https://www.nasa.gov/smallsat-institute

NASA Sponsored Small Missions Study Phase

- Planetary
  - Aeolus, APEX, BOLAS, CAESAR, Chariot, CubeX, Cupid's Arrow, CUVE, JUMPER, SNAP
- Heliophysics
  - AWE, FOXSI, MEME-X, MUSE, PUNCH, SunRise, TRACERS

JPL-led or JPL participation

Note: Small Spacecraft Systems Virtual Institute Maintains Mission Inventory https://www.nasa.gov/smallsat-institute

CubeSat Current and Upcoming Technologies

- **Power** – 10s of W_e for upcoming systems
  - Solar power limited by maximum area of deployed solar arrays and by ability to dissipate waste heat
  - Developing low temperature battery/ultracapacitor
- **Telecom** – 1 Mbps common now (for Earth orbiters), IRIS
  - Optical communication being developed – potential for Gbps communication
  - Developing inflatable antenna
- **Attitude Control System** – most CubeSats have 1-2 degree pointing accuracy
  - Upcoming missions achieving 0.1 degree or better
  - Developing miniaturized star trackers
- **Propulsion** – cold gas allows for ~10 m/s ΔV
  - Maturing chemical and electric propulsion (MEP) that is compatible with CubeSat requirements
- **Thermal** – most CubeSats have passive thermal systems

Conference Calendar

Date	Meeting
04/30/2018 San Luis Obispo, CA	**CubeSat Developer's Workshop and GSFC/JPL SmallSat Reliability TIM** http://www.cubesat.org https://www.nasa.gov/smallsat-institute/reliability-initiative
05/07/2018 Pasadena, CA	**Interplanetary Small Satellite Conference** http://www.intersmallsatconference.com
05/29/2018 Paris, France	**7th Interplanetary CubeSat Workshop** https://icubesat.org
06/12/2018 NASA ARC, CA	**20th Annual Small Payload Rideshare Association Symposium** https://sprsa.org
07/14/2018 Pasadena, CA	**42nd COSPAR Scientific Assembly** https://www.cospar-assembly.org
07/23/2018 Valencia, Spain	**International Geoscience and Remote Sensing Symposium** https://igarss2018.org
08/04/2018 Logan, UT	**Small Satellite Conference** http://www.smallsat.org/
08/19/2018 San Diego, CA	**SPIE Optics + Photonics** https://spie.org/conferences-and-exhibitions/
10/01/2018 Bremen, Germany	**International Astronomical Congress** https://www.iac2018.org/
12/10/2018 Washington, DC	**Fall AGU Meeting** https://fallmeeting.agu.org/2018

IEEE Aerospace Conference

- 8.11 Planetary Exploration Using Small Spacecraft
  - This session will explore technologies and mission concepts for planetary science and exploration throughout the solar system, addressing innovative science and exploration concepts and solutions to technical challenges associated with small spacecraft, such as: power generation in low insolation environments, thermal management in extreme environments, long-distance communications, radiation tolerance, and ways to improve spacecraft longevity given long transit times.

  - A 300-500-word abstract is due by **July 1, 2018** at the conference website: https://www.aeroconf.org